APPLICATION OF VICTOR H. NELSON

for a

ROTARY ACTUATOR

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Field of the Invention:

The present invention relates generally to the field of actuators and more particularly to a rotary actuator in which a holding, or latching torque and return torque, may be set or varied.

Background of the Invention:

The prior art relating to electrically operated rotary actuators includes U.S. Patent 6,518,685 for a Multi-Position Actuator or Sector Motor. Such an apparatus is essentially a three position actuator which includes three electromagnetic poles. An air gap of one or more of the electromagnetic poles is made different from an air gap of the remaining pole or poles in order to adjust operating characteristics of the actuator. The gap can be set for operation as a limited range actuator or as a continuous rotating device.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide a two position rotary actuator in which the latching torque can be varied easily.

ANOTHER OBJECT of the present invention is to provide a bi-directional rotary actuator whose return torque to an initial position, when electrical power is removed, may be varied.

YET ANOTHER OBJECT of the present invention is to provide a rotary actuator which comprises a relatively small number of component parts resulting in reliable long term operation.

The foregoing objects and advantages of the invention will appear more clearly hereinafter.

In accordance with the present invention there is provided a two-position rotary actuator which includes three poles and which has a latching or holding torque which can be adjusted by altering magnetic properties of a selected one of the three poles.

The actuator also functions as a sector-motor over a selected range of angular motion. Failsafe operation is provided whereby the actuator returns to a starting position when electrical power is removed and return torque of the actuator may be adjusted by altering magnetic properties of a selected one of the three poles.

BRIEF DESCRIPTION OF THE DRAWINGS

Other important objects and advantages of the present invention will be apparent from the following detailed description of the invention taken in connection with the accompanying drawings in which:

FIGURE 1 is a schematic view of a rotary actuator according to the present invention;

FIGURE 2 is a plot of a graph showing a range of latching torque plotted against rotational position of the actuator;

FIGURE 3 is a schematic view showing variation of air gap of one of the poles;

FIGURE 4 is a schematic view of an actuator according to the invention in which the shape of the pole is varied;

FIGURE 5 shows an actuator according to the invention which incorporates a screw adjustment;

FIGURE 6 shows an actuator according to the invention which incorporates a permanent magnetic;

FIGURE 7 shows an actuator whose armature is spaced close to a housing wall to provide added winding capability along with latching torque;

FIGURE 8 shows a failsafe actuator with limited range;

FIGURE 8A is a plot of a graph showing the limited range of return torque of the actuator against rotational position of the failsafe actuator;

FIGURE 9 shows a failsafe actuator with extended range which includes an angularly offset magnetic pole; and

FIGURE 9A is a plot of the extended range return torque for the unit in FIGURE 9.

DETAILED DESCRIPTION OF THE INVENTION

With reference to the drawings there is shown in **FIGURE 1**, a rotary actuator **10** made in accordance with the present invention which includes a pair of poles **12, 14** positioned around a permanent magnet radially magnetized with north and south pole armature **16.** Surrounding the poles **12, 14** and the armature **16** is a housing **18.** The housing **18** preferably is made of soft iron. Poles **12, 14** are made of a magnetic material such as soft iron. The rotary actuator also includes a third pole **20.** The three poles **12, 14** and **20** generally are equally spaced within the housing **18.** The permanent magnet usually is neodymium, alnico or a similar material.

The rotary actuator **10** includes a pair of stops **22, 24** which, as shown in **FIGURE 1**, are positioned typically at minus forty-five degrees (-45°) and plus forty-five degrees (+45°) from a zero degree (0°) position. As is shown in **FIGURE 1,** the zero degree (0°) position is defined by the position of the third pole **20.** The stops **22, 24** engage a stop arm **26** which projects from the armature **16** and which limits motion of the armature **16.** The armature **16** is mounted on a bearing **17** for rotation relative to the housing **18.** The armature **16** includes a permanent magnet with radial north and south poles that interact with the stationary poles to produce rotation.

An air gap **28** provided for the pole **20,** is different from air gaps **30, 32** provided for the poles **12, 14.** And the air gap difference results in a difference in magnetic behavior of the pole **20** relative to the magnetic behavior of the poles **12, 14.** The difference in magnetic behavior results in a latching torque during a de-energized state of the rotary actuator **10** as is

shown in **FIGURE 2** to stops **24** and **26**. The air gap **28** as shown in **FIGURE 1** is larger than the air gaps **30, 32.** Alternatively, the air gap **28** may be made smaller than the air gaps **30, 32,** resulting in a latching torque to the zero (0°) position. **FIGURE 2** shows a range of latching torque determined by the differences in magnetic behavior between pole **20** and poles **12** and **14.** For gap **28** larger than gaps **30** or **32.**

When the stop arm **26** contacts each of the stops **22, 24** there is a holding or latching torque present whose magnitude depends on difference in the magnetic behavior of the pole **20** relative to the poles **12** and **14.** If each of the poles **12, 14, 20** had exactly equal magnetic behavior with equal air gaps **28, 30, 32** there would be zero latching torque. A maximum latching torque is obtained when the gap **28** is a maximum or when pole **20** of **FIGURE 1** is omitted. The omission of the pole **20** results in a non-symmetrical configuration of the poles **12, 14** relative to the armature **16.**

The latching torque may also be altered by altering shape of pole **34,** as is shown in **FIGURE 4**, and/or by altering material of the pole or mounting a permanent magnet **36** to the pole **38,** as is shown in **FIGURE 6.**

Applying electrical power to the coils **40, 42** on the poles **12, 14** produces a useful sector motor, by overcoming the latching or holding torque and driving the armature **16,** which may be connected to a load, through a range established by the stops **22, 24.**

FIGURE 3 shows a pole **44** which has a relatively large air gap **46** or space between the end **48** of the pole **44** and the armature **16.** This air gap may be varied from the relatively large gap **46** as is shown to a relatively narrow gap **50** which is indicated schematically by the

broken lines **52** in **FIGURE 3** thereby increasing the latching torque or decreasing the hold torque accordingly.

FIGURE 4 shows a pole **34**, according to the present invention, which has a cross-sectional area which increases from a relatively narrow portion **54** (which is disposed relatively close the air gap **56**) to a relatively wide portion **58** disposed relatively close to the housing **18.**

FIGURE 5 shows a threaded pole member **60** which is made of a ferromagnetic material. The pole member **60** is threadably received in the housing **18** and rotation of the pole member **60** relative to the housing as shown by arrows **63, 65** and facilitates adjustment of the air gap **62** between the end **64** of the pole member **60** and the armature **16.**

FIGURE 6 shows a pole member **38** which incorporates a permanent magnet **36** which is mounted on an end **66** of the pole member **38.** The pole member **38** may be made of a ferromagnetic material.

FIGURES 3 - 6 thus illustrate various pole member configurations of the present invention which provide a range of magnetic properties that differ from each other and also differ from the pole members **12** and **14.**

FIGURE 7 shows spacing the armature assembly **68** close to the housing wall **70** to inherently produce a suitable gap **72,** different than gap **74** or **76** and to provide an increased winding capability on poles **78, 80** to provide more ampere turns which will increase the drive torque.

FIGURE 8 illustrates the failsafe operation of the actuator **82.** When powered, the actuator **82** drives the stop arm **84** to the stop **86.** Removing the power returns the stop arm **84** to the stop **88.** The actuator **82** thus provides a failsafe mode. **FIGURE 8A** also illustrates the useful range of the actuator which extends between the vertical marks **90, 92,** This range extends from approximately 10° to approximately 85°. As shown in **FIGURE 8A,** in broken lines the return or the latching torque may be changed by altering the magnetic properties of pole **94.** As is shown in **FIGURE 9** the useful range of the actuator 86 may be extended 90° and beyond 90° by incorporating the pole **98** which is similar to the pole **28** shown in **FIGURE 6.** The pole **98** is angularly offset to react against the armature magnet **100.** The return torque may be varied by altering the gap **102** by adjusting the position of the magnet **104** by rotating the adjustment screw **106.** The variation in return torque is illustrated by the variation illustrated by the solid line **108** and the broken line **110** in **FIGURE 9A.** The actuator **96** includes the stop arm **112** and the stops **114** and **116.**

The foregoing specific embodiments of the present invention as set forth in the specification herein are for illustrative purposes only. Various deviations and modifications may be made within the spirit and scope of this invention without departing from a main theme of invention delineated more specifically in claims that follow herein.